16.1 Human Skeleton

Human's skeleton is the main supportive framework of the body. It mainly includes bones and cartilages. The muscles are attached to the skeleton for the production of effective movements of the body.

Skeletal tissues:- Skeletal tissues are bone or cartilage

Bone:- Bone is one-third of connective tissue. It is impregnated with calcium salts. The composition of bone tissue is different from other tissues in the body. Bone is a hard tissue, provides support to the body, gives environment for the production of blood cells and protects internal organs of the body.

16.1.1 Structure of Bone

Bone tissues are of two types; **compact** (hard and dense) and **cancellous** (spongy) tissues. The outer part of bone is hard, called compact bone while the inner part is spongy, called spongy bone.

Compact bone

Compact bone, also called **cortical bone**, is a hard white bone tissue that surrounds all the bones in human body. The fundamental units of compact bone are called **osteons** or **Haversian systems.** Each osteon consists of concentric layers called **lamellae** (singular: lamella). In the centre of each osteon, **central canal** or **Haversian canal** is present which contains blood and nerve supply of the bone. The central canal communicates with the **perforating canal** (also called **Volkmann's canal**), which transmits blood vessels from periosteum (a dense layer of vascular connective tissue enveloping the bone) into the endosteum (The thin layer of cells lining the medullary cavity of a bone).

The **osteocytes** are located in the small cavity called **lacunae** (singular: lacuna), situated between the lamellae. **Canaliculi** are the microscopic channels that create a network which transport nutrients, to the osteocytes and also remove wastes from them.

Spongy bone

Spongy bone, also called cancellous or **trabecular bone**, is a porous and highly vascular bone. It is mostly located at the end of the long bones. Unlike compact bone, the lacunae of spongy bone are found in a lattice-like network of matrix spikes called **trabeculae** (singular: trabecula). The **osteocytes** of spongy bone are irregularly placed within the trabeculae. The spaces between trabeculated networks make spongy bone lighter and less dense than compact bone. The spaces in some spongy bones contain **red bone marrow**, where the blood cells are formed. (Fig.16.1)

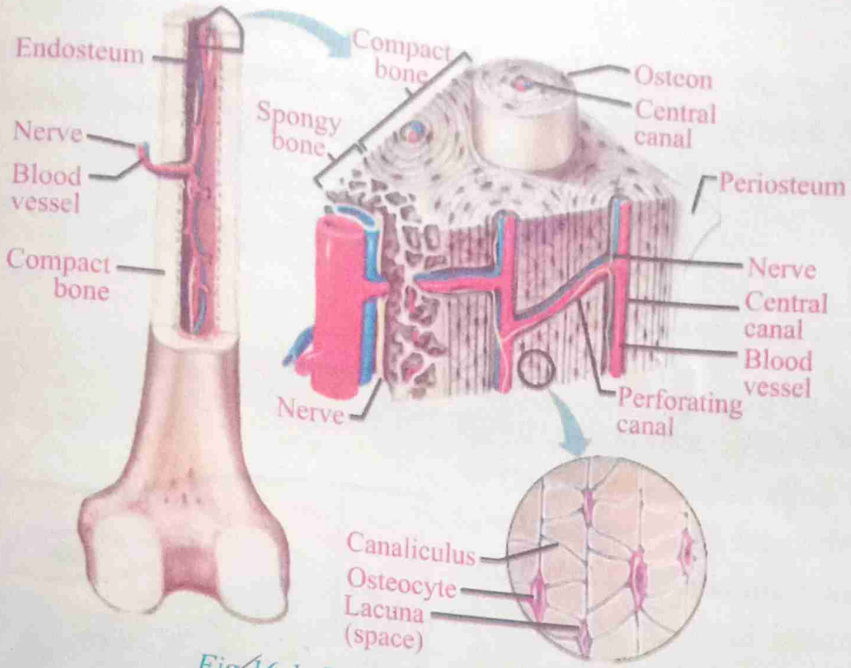

Fig.16.1: Internal Structure of Bone

Types of Bone Cells

The process of bone growth and repair is carried out by four different types of cells. These cells are involved in making and breaking the bone.

1. **Osteogenic Cells** are the stem cells that are found in the cellular layer of endosteum and periosteum. These are undifferentiated cells and have ability to divide. The osteogenic cells develop into osteoblasts.

2. **Osteoblasts** are involved in the formation of new bone. They are mostly found in the areas where bone growth occurs. These cells secrete collagen.

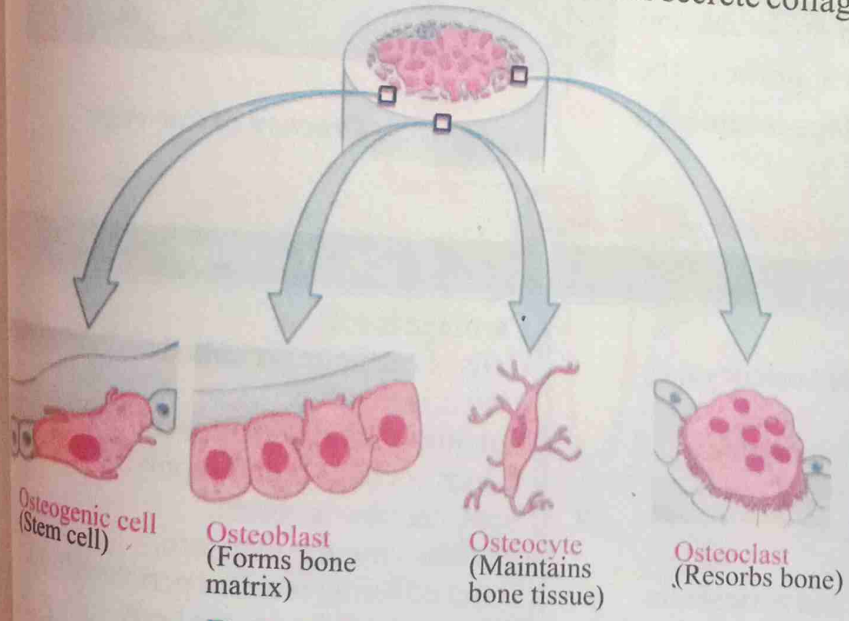

Fig.16.2: Types of Bone Cells

Extra Information

A new "inner you" is about ten years old. In adult human every year about 10% bone is replaced, that means as the mineral content in bones is renewed, we get a new skeleton about every ten years.

3. **Osteocytes** are matured bones cells and are entrapped in the matrix. When osteoblasts are surrounded by the matrix, they become osteocytes. By the help of secretion of enzymes, osteocytes maintain mineral concentration of the matrix.

4. **Osteoclasts** take part in bone resorption and breakdown processes. These cells are found at the sites of old, injured bone. Osteoclasts are multinucleated and are derived from **monocytes and macrophages**. (Fig.16.2)

16.1.2 Cartilage

Cartilage is a connective tissue compos-ed of cells called **chondrocytes** and fibers embed-ed in a firm, gel like matrix. It is much more elastic than bone. Cartilage is found in many areas of the body including joints, between the bones, *e.g.* the elbow, knees and ankles.

The general features of cartilage include that it has no blood vessels or lymphatics. The nutrition of cells diffuses through the matrix. Cartilage has no nerves, it is therefore, insensitive. Cartilage is surrounded by a fibrous membrane called **perichondrium**, which is similar to periosteum in structure and function. When cartilage calcifies, the chondrocytes die and cartilage is replaced by bone like tissue. (Fig.16.3)

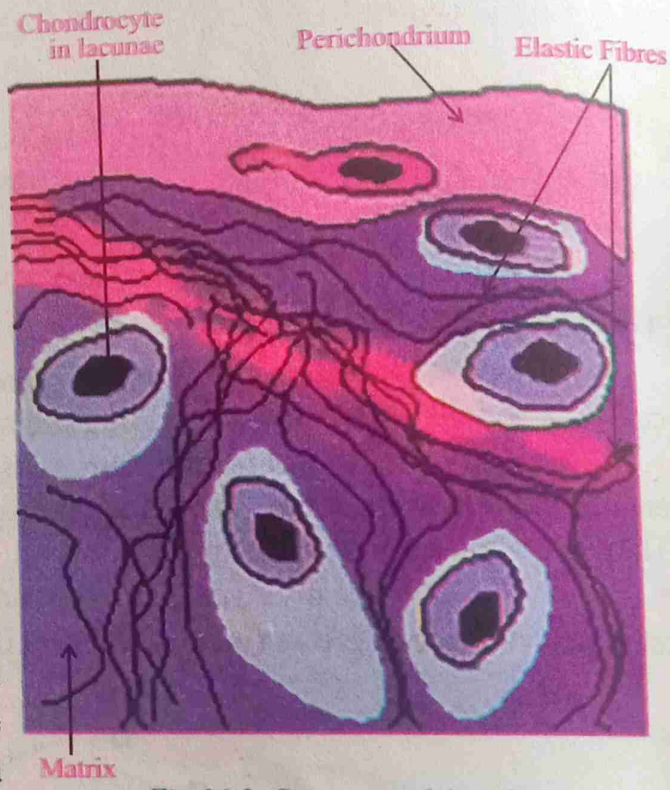

Fig.16.3: Structure of Cartilage

Table 16.1 The comparison between bone and Cartilage

S.No.	Bone	Cartilage
i)	Bone is hard.	Cartilage is soft.
ii)	Cells of bone are called osteocytes.	Cells of cartilage are called chondrocytes.
iii)	Matrix is inflexible.	Matrix is flexible.
iv)	Matrix possesses calcium salts.	Calcium salts are not present.
v)	Bone has rich blood supply.	It does not have blood supply.
vi)	Bone marrow is present.	Bone marrow is absent.
vii)	It is vascular in nature.	It is non-vascular in nature.
viii)	Outer covering is called periosteum.	Outer covering is called perichondrium.
ix)	Provide skeletal support to the body.	Provide flexibility to the body.

16.1.4 Joints

Joint is the point of attachment between two bones or bone and cartilage. There are more joints in a child than in adult because some of the bones fuse together as the growth proceeds. There are 360 joints in adult human skeleton. The scientific study of joints is called **arthrology**.

Extra Information

Ligaments are short bands of tough fibrous connective tissue that function to connect one bone to another bone in the joint.

Types of joints

On the basis of tissue present in the joint, there are three types of joints: fibrous joints, cartilaginous joints and synovial joints.

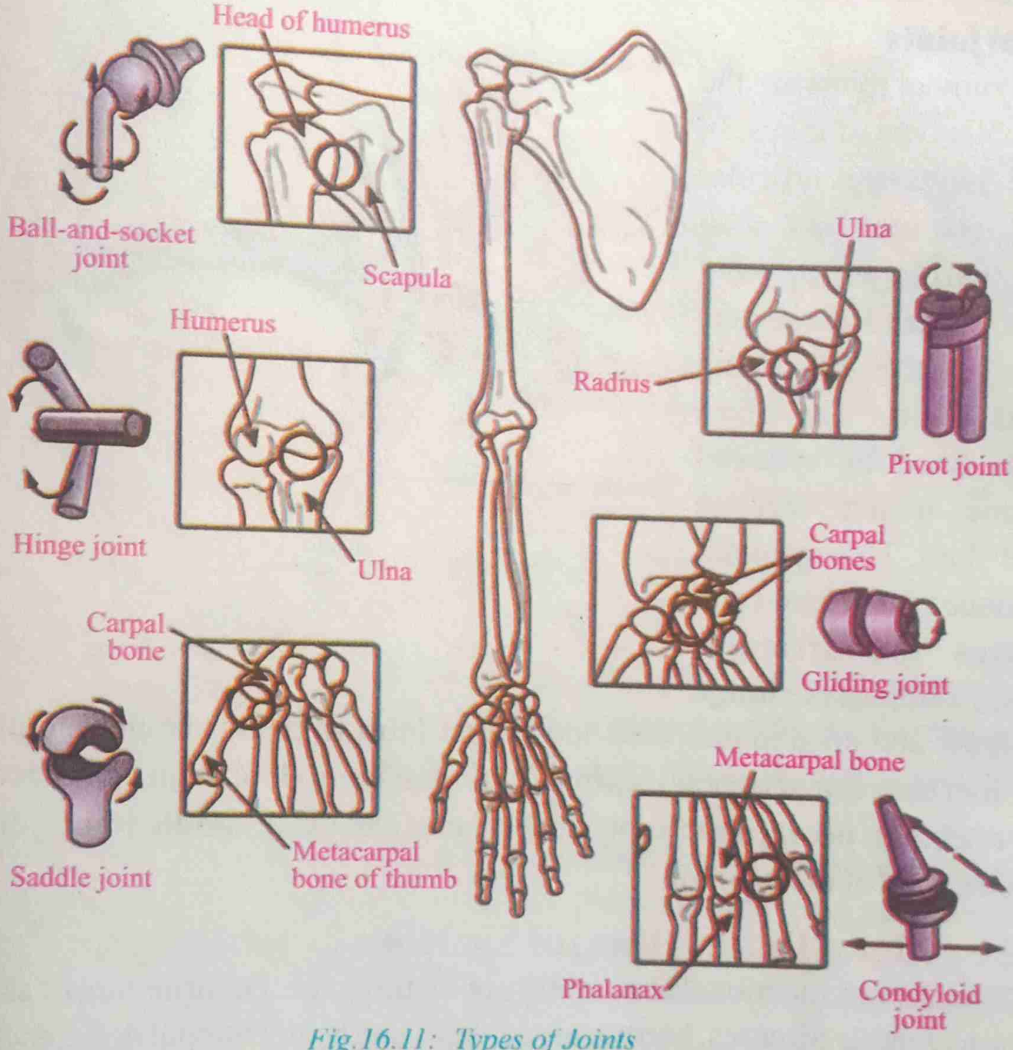

Fig.16.11: Types of Joints

Fibrous joints

When the articular surface of the bones are connected to each other by fibrous connective tissue, it is called **fibrous joint**. Fibrous connective tissue is a dense

connective tissue consisting mainly of collagen. These joints are also called immovable joints because they do not allow movement. Examples, includes joint between skull bones called **sutures**, joint between tooth and its socket and joint between long bones e.g. tibia and fibula.

Cartilaginous joints

When the articular surface of the bones is connected by cartilage (fibrocartilage or hyaline cartilage), it is called **cartilaginous joint**. These joints are also called **slightly movable joints** because they allow little movement. **Hyaline cartilage** is seen in the costal cartilages that attach ribs to the sternum, **fibrocartilage** is seen in intervertebral disc and pubic **symphysis**.

Synovial joints

Synovial joints are the most mobile type of joints. In synovial joints the articular surfaces are covered with hyaline cartilage. A joint cavity is present between the articular surfaces filled with synovial fluid. The joint cavity is lined by synovial membrane which secretes synovial fluid. This **synovial fluid** reduces the friction and lubricates the articular surfaces. Examples are **hinge joint** (elbow and knee joints), **ball and socket joint** (hip and shoulder joints), **gliding joint** (joints between vertebrae), **ellipsoid joint** or **condyloid joint** (joint between skull and 1st vertebrae), **pivot joint** (joint between atlas and axis), **saddle joint** (joint between carpometacarpal of the thumb).

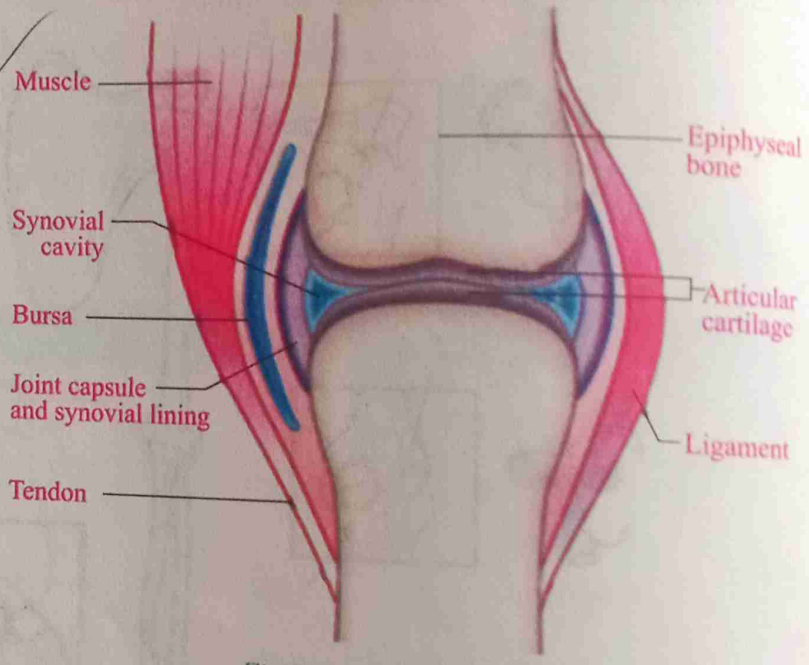

Fig.16.12: Synovial Joints

16.2 Disorders (Deformities) of Skeleton

Disorder is a functional abnormality or disturbance. Deformation of skeleton may occur due to genetic diseases, hormonal problems and by nutritional deficiencies.

16.2.1 Common Disorder of Skeleton

Some common conditions that affect the skeletal system include slip disc, spondylosis, sciatica and arthritis.

leg. Recovery from sciatic injury is usually slow and incomplete.

Common causes of sciatica include; a herniated disc, any injury to proximal sciatic nerve, **spondylolisthesis** (a condition in which one vertebra slips forward over another one), muscle spasm in the back or buttocks, improper administration of injection into the buttocks. The pregnant women have a great chance of getting a herniated disc and develop sciatica. Diabetes can also cause nerve damage.

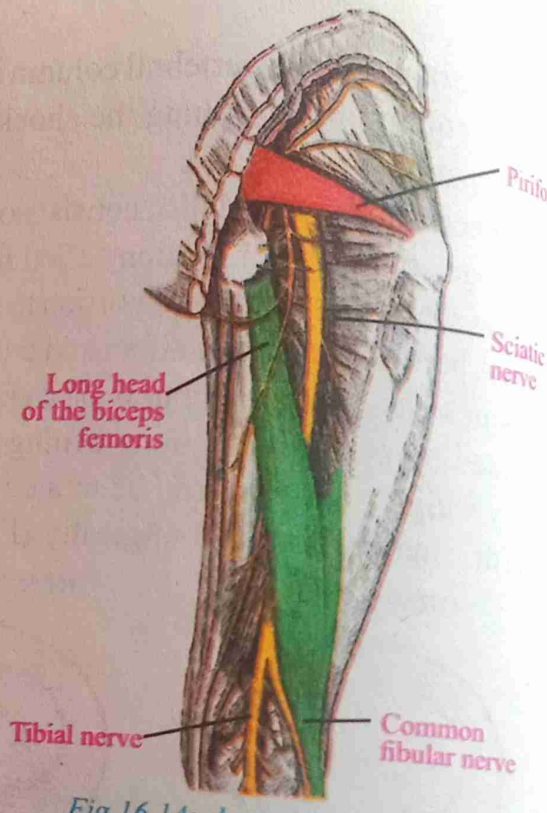

Fig.16.14: Location of Sciatic Nerve in Leg

Arthritis

Arthritis is the **inflammation of joint**. In this disease the joints become swollen, stiffer and painful. The membrane lining of the joint thickens, fluid production is decreased which leads to increase friction.

An infection or injury to the joints, abnormal metabolism and immune system dysfunction are the possible causes of arthritis. Sometimes, it may be caused by inheritance such as in **osteoarthritis**.

Chronic arthritis includes osteoarthritis, rheumatoid arthritis and gouty arthritis. **Osteoarthritis** is the most common type of arthritis. It can cause inflammation of any joint. It occurs when the joint cartilage is degenerated.

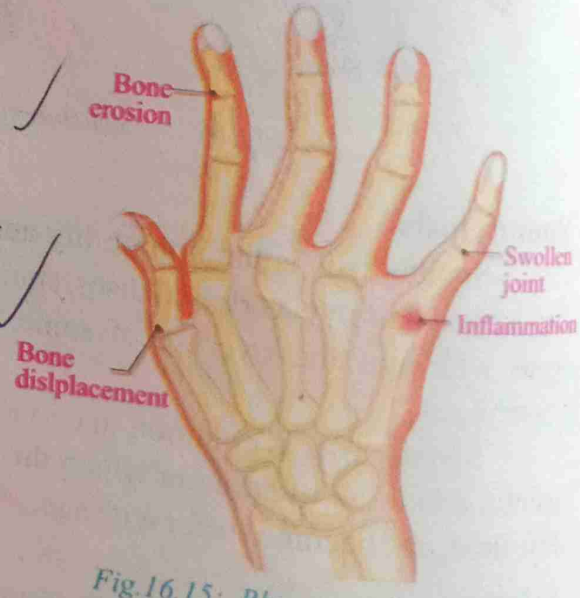

Fig.16.15: Rheumatoid Arthritis

Rheumatoid arthritis is the inflammation of hand and wrist joints. **Gouty arthritis** develops in people who have high level of uric acid in their blood. It is caused by the deposition of needle like crystals of uric acid in a joint.

16.2.2 Bone Fracture

When there is a partial or complete break in the continuity of the bone, it is called bone fracture. Fractures occur mostly when a bone is impacted by more force than it can

16.2.5 First aid treatment for fractures

First aid treatment is very useful for fractures as it prevents further injury and promote recovery. There are following first aid treatments for fractures.

1. Apply pressure to the injured area to control any bleeding. Pressure can be applied with the help of clean cloth or bandage.
2. Immobilize the injured area by providing support. This can prevent any further damage.
3. Apply ice packs to the injured part. This will limit swelling and relives pain. Don't apply ice directly to the skin, wrap the ice in a towel or cloth and apply it to the injured area for up to 10 minutes.
4. Keep checking the casualty for signs of shock. If the patient loses responsiveness, check his/her breathing rate and help patient get into a comfortable position.

Extra Information

The largest muscle of the body is gluteus maximum which is main extensor muscle of the hip. It supports the trunk and maintain proper posture.

16.3 Muscles

The muscle is a contractile tissue found in animals. The primary function of muscle is to produce movement. Besides movement muscles also hold body parts in postural positions, movement of the body fluids and heat production. The study of muscles is called **myology**.

16.3.1 Types of Muscle

There are over 640 muscles in the body of human which are divided into following three groups:

Skeletal Muscles

These are located on skeleton so called skeletal muscles. They are **voluntary muscles**, meaning that we can control them at will. They typically control movement

through activation by the somatic branch of peripheral nervous system with a rapid speed of contraction. Skeletal muscles also play a role in temperature regulation, using rapid muscle contraction. They are striated, meaning that its tissue is crossed with light and dark bands. They get fatigue easily. (Fig.16.17a)

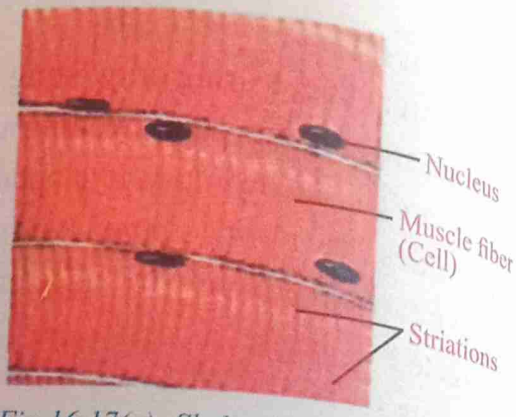

Fig.16.17(a): Skeletal Muscle

Smooth Muscles

Smooth muscles are **involuntary muscle** tissue controlled by the automatic nervous system. They are located in all visceral organs (except heart) such as the stomach, intestines, bladder as well as our blood vessels. Smooth muscle contracts more slowly than skeletal and cardiac. The function of smooth muscle is to move substance through an organ or vessel. It does so by contracting in waves, known as **peristalsis**. The cells of these muscles are **spindle shaped** with a single nucleus located in the middle of the cell. They do not get fatigue.

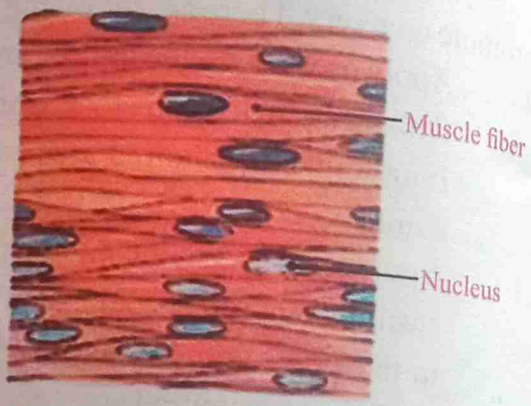

Fig.16.17(b): Smooth Muscle

Cardiac Muscles

They are located only in heart. They are involuntary muscles so controlled by autonomic nervous system. Like skeletal muscle, these muscle cells are also striated. In between its fibres are intermittent spaces, which contain connective tissues and many capillaries to ensure a constant supply of oxygen. The cells are **uninucleated** and branched. Adjacent cells joint together to form branching fibres by specialized cell to cell attachment called **intercalated discs**. The comparison of these three types of muscles are given in table 16.4. (Fig.16.17c)

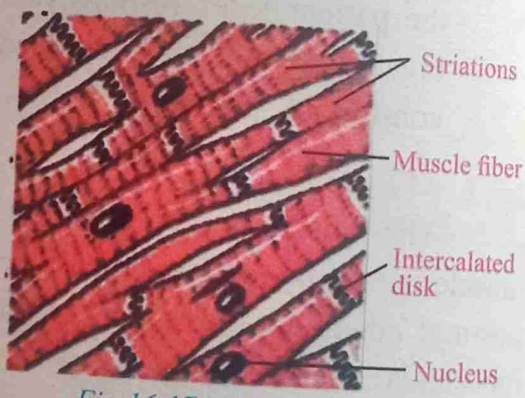

Fig.16.17(c): Cardiac Muscle

Extra Information

The hardest working muscle in the body are cardiac. The heart pump about 2500 gallon of blood per day.

Table 16.4: Comparison of Three Types of Muscles

	Skeletal	Cardiac	Smooth
Location	Attached to bones	The heart	Internal organs and skin
Shape	Elongated and cylindrical 	Branched 	Spindle 
Nucleus	Several peripherally located nuclei	Single centrally located nucleus	Single centrally located nucleus
Striation	Striated	Striated	Non-striated
Function	* Movement of bone * Heat production	Beating of the heart	Movement of the viscera
Control	Voluntary	Involuntary	Involuntary

16.3.2 Structure of skeletal muscles

Each skeletal muscle is attached with two bones. The end of skeletal muscle attached with immovable bone is called origin of muscle, while the other end of skeletal muscle is attached with moveable bone is called insertion of muscle. The muscle attaches with bone by a connective tissue known as tendon. Within a typical skeletal muscle is a bundle of long fibres running parallel to the length of muscle. Each fibre is a single cell with multi nuclei (each nucleus is derived from one of the embryonic cell). These embryonic cells fused to form the muscle cell. Inside a muscle cell lies a longitudinal bundle of myofibrils, which contain the thin and thick filaments. Each thin filament mostly consists of **actin filaments**. The thick filaments are called **myosin**. The **myofibrils** are made up of repeating sections called **sarcomeres**, which are the basic contractile units of skeletal muscle. Theborders of the sarcomere

Extra Information

The smallest muscles (stapedius) of the body lie in the ear along with smallest bone (Stapes), while the strongest muscle, based on its weight, is the masseter, in the jaw.

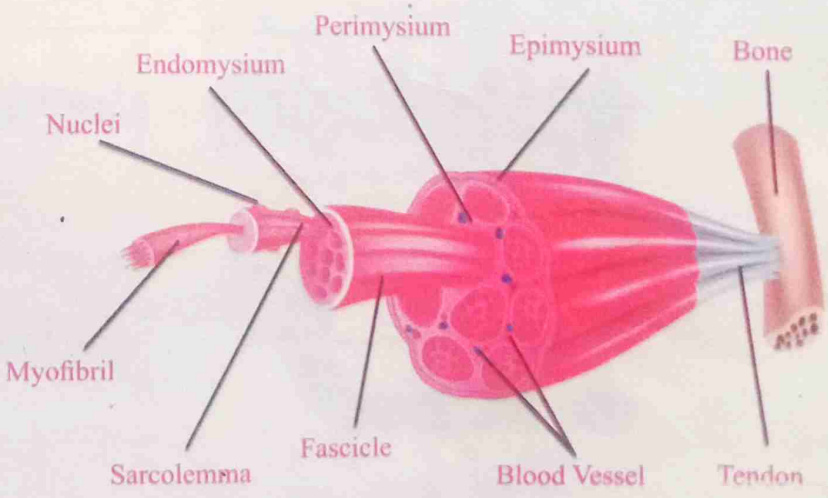

Fig.16.18: Structure of Skeletal Muscle

line up in adjacent myofi-brils, forming a pattern of light and dark bands (striations) visible with light microscope. That is why skeletal muscles are called **striated muscle**. The thin filament attached with **Z line** (zwisch line means between), while thick filaments are anchored at M-lines **(middle line)** centered in sarcomere. In relaxed state, the thick and thin filaments partially overlap. Near the edge of sarcomeres there are only thin filament and this portion of sarcomere is called I-band (isotropic). The zone of sarcomere in the center contains thick band and called A-band (Anisotropic) *i.e.* complete length of myosin partially covered by actin filament. The middle portion where only myosin filaments are present are called **H-Zone** (Hele Zone means bright). This arrangement is the key to how the sarcomere and whole muscle contract.

Ultra-structure of Skeletal Muscles

The sarcomere is the structural and functional unit of muscle fibre (muscle cell). A muscle fibre is a cylindrical cell which contains all the parts of a typical cell like plasma membrane (sarcolemma), cytoplasm (sarcoplasm), endoplasmic reticulum (sarcoplasmic retialum), mitochondria, nuclei, *etc.*

Extra Information

Muscles are built during sleep, not in gym or during exercise because at this time more blood circulation and hormones are released.

Under electron microscope, in the sarcomere two types of filaments are visible. Thick filaments are called myosin while thin filaments are called actin.

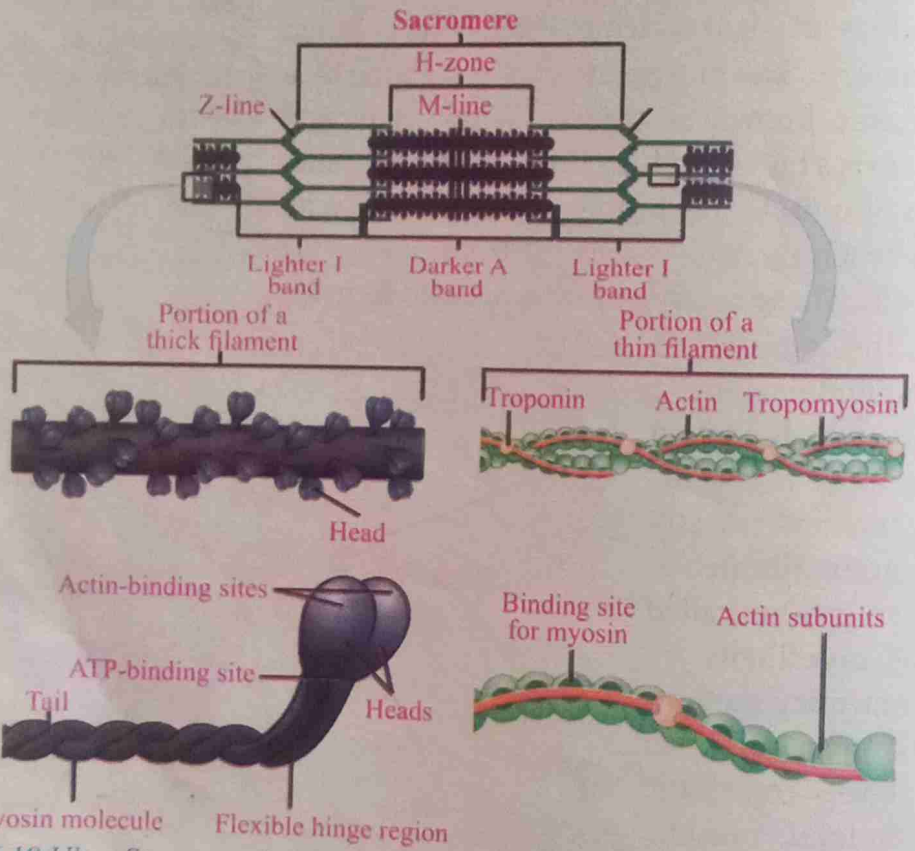

Fig. 16.19 Ultra Structure of Actin-myosin Filaments and Structure of Muscle Fibre

Myosin filament

These filaments consist of myosin protein. Each thick filament is 15nm in diameter. Each filament consists of hundreds of molecules of myosin protein. A myosin molecule is shaped like a golf club, with a tail formed of two intertwined chains and a double globular head projecting from it at an angle. Half of the myosin heads projecting from it at an angle to the left and half of them angle to the right, creating an area in the middle of the filament known as bare zone.

Actin filament

Thin filaments are called actin filaments. An actin filament is about 7nm in diameter, and consists primarily of actin protein. There are two chains of actin protein molecules twisted together, each actin filament also contains 40-60 molecules of **tropomyosin**, the protein which block the active sites of thin filaments when the muscle is relaxed. Each tropomyosin molecule has a smaller calcium binding protein called troponin, is bound to it. (Fig.16.19).

16.3.3 Muscle contraction – sliding filament model

According to sliding filament theory of muscle contraction, the actual length of actin and myosin filament does not change but actin filaments slide over myosin filaments. The actual trick is played by myosin filaments. This happens when myosin

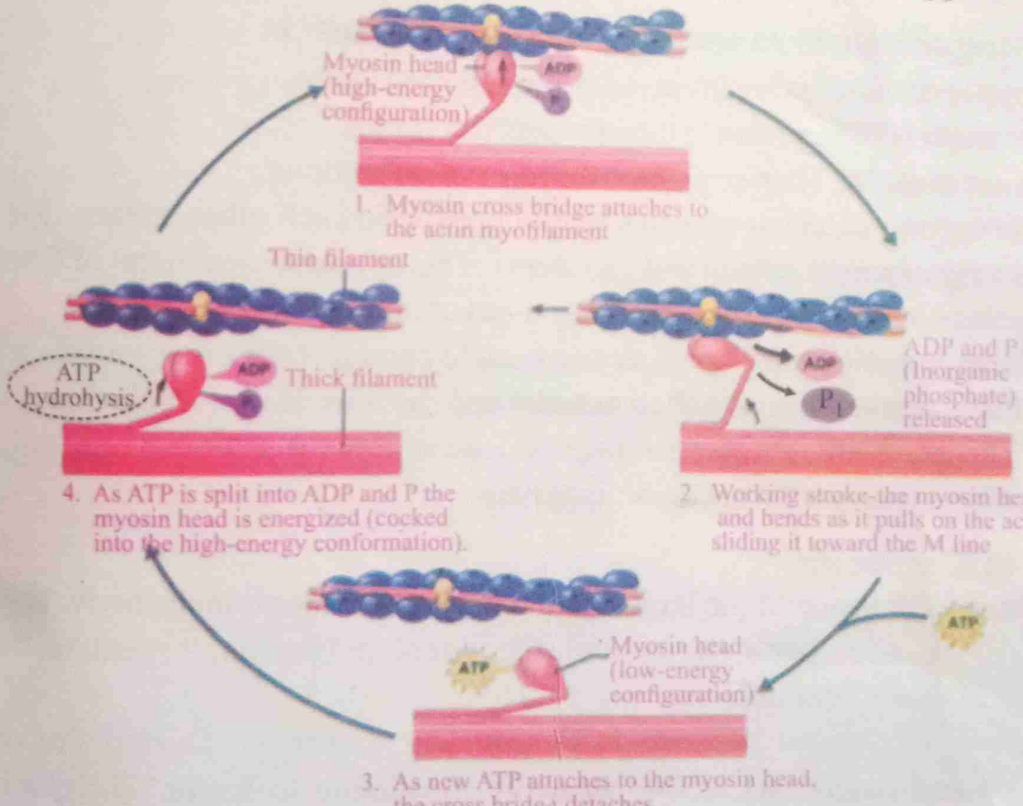

Fig.16.20: Sliding Filament Model

heads attach with actin filament at the site of troponin protein. When these heads bend, these pull the actin filaments over the myosin filaments. This theory was proposed by Z. Huxley and A.F Huxley in 1954. During full muscle contraction the I-band and H-zone disappear and only dark zone *i.e.* A-band appears. During the sliding process the Z-lines come close together and as a result sarcomere shortens. ATP provides energy for muscle contraction. The sliding filament theory or model is universally accepted. (Fig.16.20)

Control of Cross Bridges and Role of Calcium Ions

Muscle contraction is initiated when nerve impulse arrives at the **neuromuscular junction** within the muscle fibre, the action potential spreads deep into the interior, following infolding of plasma membrane called **transverse tubules** (T-tubules). These make close contact with the sarcoplasmic reticulum (SR). As the action potential spreads along the **T-tubules**, it triggers changes in SR, opening Ca^{++} channels. Calcium ions stored in the SR flow through open channels into the cytosol and bind to the troponin protein and cause them to slightly move. As a result, tropomyosin diphase and expose the binding site for myosin head. Once the myosin head attaches with actin filament, ATP is hydrolysed to adenosine diphosphate (ADP) and inorganic phosphate (Pi) and the cross bridges are broken down. The formation and break down of cross bridges occur again and again and movement of muscle occurs.